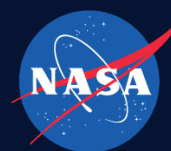


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ANTICIPATED BENEFITS

To NASA funded missions:

Robotic Refueling Mission - Phase 1: Multiple Robotic Refueling Mission - Phase 2: Multiple; future anomalies Raven: Orion Ammonia Leak Locator: Outsourcing the task of finding ammonia leaks to a tireless, teleoperated robotic tool would free astronauts to use spacewalks to address such leaks instead of search for them

DETAILED DESCRIPTION

This project advances the state of robotic technology to enable the routine servicing of satellites that were not designed with servicing in mind, including observatories and space infrastructures. It improves technologies necessary for robotic satellite servicing, rescue, and disposal, particularly technologies for the remote survey, relocation, refueling, replacement (of orbital repair units), and repair of orbiting satellites. Primary project activities include developing a conceptual robotic servicing mission for Government and commercial satellites, as well as an aggressive technology development campaign to rapidly advance the TRL of multiple cross-cutting technologies. The campaign includes the:

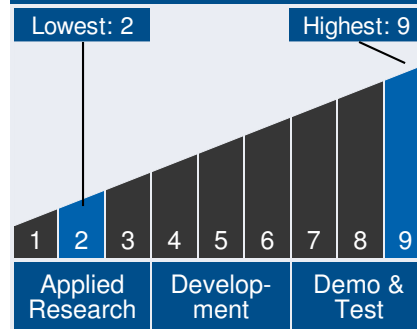
- Robotic Refueling Mission, a technology demonstration on the International Space Station (ISS) that uses the Canadian Dextre robot and NASA-developed tools and task boards to demonstrate tools, technologies and techniques to refuel and repair satellites that were not designed for in-flight service. Operations to date have included the most dexterous robotic maneuvers performed on orbit.



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Technology Maturity



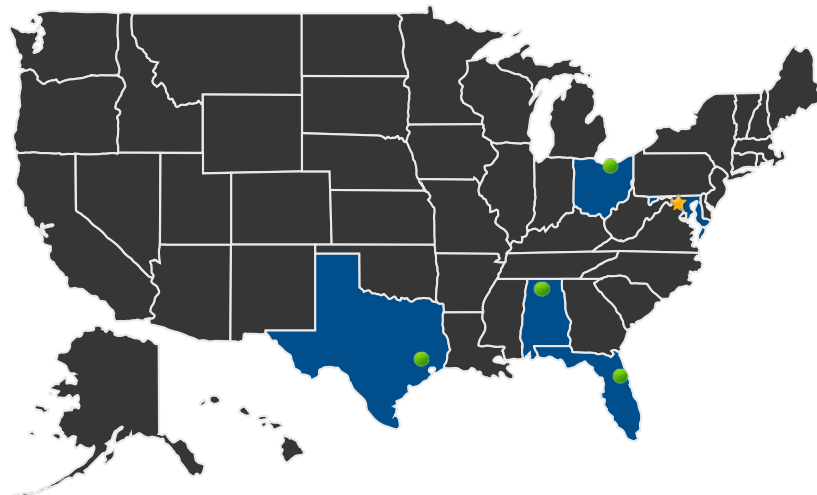
Management Team

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U.S. WORK LOCATIONS AND KEY PARTNERS



■ U.S. States
With Work

★ **Lead Center:**
Goddard Space Flight Center

● **Supporting Centers:**

- Glenn Research Center
- Johnson Space Center
- Kennedy Space Center
- Marshall Space Flight Center

Management Team (cont.)

Program Manager:

- Mary Wusk

Project Manager:

- Benjamin Reed

Principal Investigator:

- Robert Ambrose

Technology Areas

- Robotics and Autonomous Systems (TA 4)
- System-Level Autonomy (TA 4.5)
- Six Degrees of Freedom (DOF) Relative Estimation for Formations and Proximity Operations (TA 8.2.3.3)
- Robotic Assembly Tools / Interfaces (TA 12.3.3.1)

DETAILS FOR TECHNOLOGY 1

Technology Title

Ammonia Leak Locator

Technology Description

This technology is categorized as a hardware subsystem for unmanned spaceflight

Ammonia Leak Locator, a tool that can locate the source and location of a leaking gas. These technology development efforts will help enable a future commercial satellite servicing enterprise

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as well as future robotic servicing and assembly of science observatories. Technologies developed for servicing will be beneficial to future human space missions, maintenance of the ISS, autonomous rendezvous and docking of space vehicles, mitigation of orbital debris, and in-space assembly of science observatories.

Capabilities Provided

Location of the source of a venting gas

Potential Applications

Location of leaks on a spacecraft

Technology Areas

Primary Technology Area:

Science Instruments, Observatories, and Sensor Systems (TA 8)

- └ Observatories (TA 8.2)
 - └ Distributed Aperture (TA 8.2.3)
 - └ Six Degrees of Freedom (DOF) Relative Estimation for Formations and Proximity Operations (TA 8.2.3.3)

Secondary Technology Area:

Robotics and Autonomous Systems (TA 4)

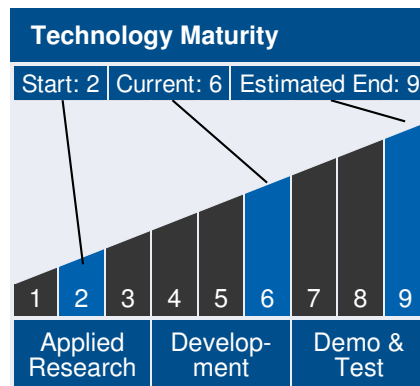
Additional Technology Areas:

Materials, Structures, Mechanical Systems and Manufacturing (TA 12)

- └ Mechanical Systems (TA 12.3)
 - └ Electro-Mechanical, Mechanical, and Micromechanisms (TA 12.3.3)
 - └ Robotic Assembly Tools / Interfaces (TA 12.3.3.1)

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DETAILS FOR TECHNOLOGY 2

Technology Title

Raven

Technology Description

This technology is categorized as a hardware subsystem for unmanned spaceflight

Raven is a demonstration on the International Space Station of a real-time relative navigation system that would enable future spacecraft to autonomously rendezvous with both prepared vehicles and those not designed for servicing.

Capabilities Provided

Autonomous tracking of non-cooperative spacecraft

Potential Applications

Autonomous rendezvous operations

Technology Areas

Primary Technology Area:

Science Instruments, Observatories, and Sensor Systems (TA 8)
 └ Observatories (TA 8.2)
 └ Distributed Aperture (TA 8.2.3)
 └ Six Degrees of Freedom (DOF) Relative Estimation for Formations and Proximity Operations (TA 8.2.3.3)

Secondary Technology Area:

Robotics and Autonomous Systems (TA 4)

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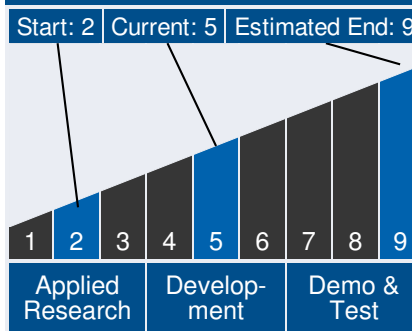


Technology Areas (cont.)

Additional Technology Areas:
Materials, Structures, Mechanical Systems and Manufacturing (TA 12)

- └ Mechanical Systems (TA 12.3)
 - └ Electro-Mechanical, Mechanical, and Micromechanisms (TA 12.3.3)
 - └ Robotic Assembly Tools / Interfaces (TA 12.3.3.1)

Technology Maturity



DETAILS FOR TECHNOLOGY 3

Technology Title

Robotic Refueling Mission - Phase 1

Technology Description

This technology is categorized as a hardware subsystem for unmanned spaceflight

RRM-Phase 1 demonstrated precise telerobotic servicing capabilities, including cutting safety wires, removing caps and gas fittings, manipulating insulation, activating valves, and

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transferring fluid.

Capabilities Provided

Hypergolic refueling

Potential Applications

Spacecraft refueling

Technology Areas

Primary Technology Area:

Science Instruments, Observatories, and Sensor Systems (TA 8)

- └ Observatories (TA 8.2)
 - └ Distributed Aperture (TA 8.2.3)
 - └ Six Degrees of Freedom (DOF) Relative Estimation for Formations and Proximity Operations (TA 8.2.3.3)

Secondary Technology Area:

Robotics and Autonomous Systems (TA 4)

- └ System-Level Autonomy (TA 4.5)

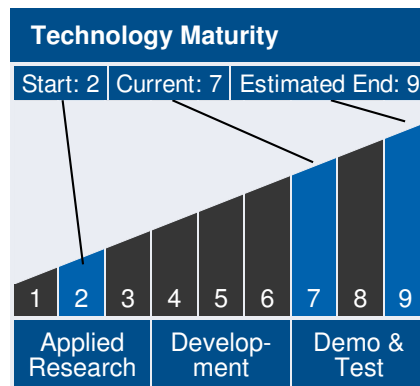
Additional Technology Areas:

Materials, Structures, Mechanical Systems and Manufacturing (TA 12)

- └ Mechanical Systems (TA 12.3)
 - └ Electro-Mechanical, Mechanical, and Micromechanisms (TA 12.3.3)
 - └ Robotic Assembly Tools / Interfaces (TA 12.3.3.1)

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DETAILS FOR TECHNOLOGY 4

Technology Title

Robotic Refueling Mission - Phase 2

Technology Description

This technology is categorized as a hardware subsystem for unmanned spaceflight

RRM-Phase 2 is demonstrating advanced solar cell technology, satellite inspection, and the intermediate steps leading up to satellite cryogen replenishment.

Capabilities Provided

In-orbit inspection and advanced solar cells

Potential Applications

Spacecraft inspection; higher-efficiency power generation

Technology Areas

Primary Technology Area:

Science Instruments, Observatories, and Sensor Systems (TA 8)
 └ Observatories (TA 8.2)
 └ Distributed Aperture (TA 8.2.3)
 └ Six Degrees of Freedom (DOF) Relative Estimation for Formations and Proximity Operations (TA 8.2.3.3)

Secondary Technology Area:

Robotics and Autonomous Systems (TA 4)

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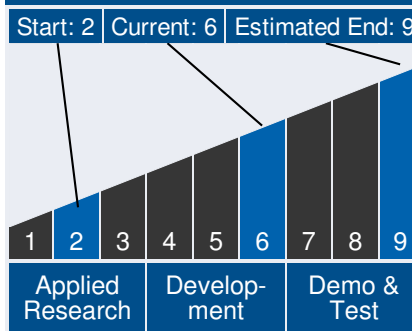


Technology Areas (cont.)

Additional Technology Areas:
Materials, Structures, Mechanical Systems and Manufacturing (TA 12)

- └ Mechanical Systems (TA 12.3)
 - └ Electro-Mechanical, Mechanical, and Micromechanisms (TA 12.3.3)
 - └ Robotic Assembly Tools / Interfaces (TA 12.3.3.1)

Technology Maturity



DETAILS FOR TECHNOLOGY 5

Technology Title

Robotic Refueling Mission - Phase 3

Technology Description

This technology is categorized as a hardware subsystem for unmanned spaceflight

RRM-Phase 3 will demonstrate in-orbit cryogen fluid manipulation.

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Capabilities Provided

In-orbit cryogen fluid manipulation

Potential Applications

Cryogen replenishment

Technology Areas

Primary Technology Area:

Science Instruments, Observatories, and Sensor Systems (TA 8)

- └ Observatories (TA 8.2)
 - └ Distributed Aperture (TA 8.2.3)
 - └ Six Degrees of Freedom (DOF) Relative Estimation for Formations and Proximity Operations (TA 8.2.3.3)

Secondary Technology Area:

Robotics and Autonomous Systems (TA 4)

Additional Technology Areas:

Materials, Structures, Mechanical Systems and Manufacturing (TA 12)

- └ Mechanical Systems (TA 12.3)
 - └ Electro-Mechanical, Mechanical, and Micromechanisms (TA 12.3.3)
 - └ Robotic Assembly Tools / Interfaces (TA 12.3.3.1)

Active Project (2009 - 2019)

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